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POMWIG : HERWIG for Diffractive Interactions

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Abstract

We have modified the HERWIG event generator to incorporate diffractive interactions. All standard HERWIG hard subprocesses are available.

1 Introduction

The modifications to HERWIG [1] that are necessary to incorporate diffractive collisions are relatively simple once it is noticed that pomeron exchange events in hadron - hadron collisions look very much like resolved photoproduction events in lepton - hadron collisions. In resolved photoproduction in electron - proton collisions, for example, the process is modeled by the incoming electron radiating a quasi-real photon according to a flux formula. The photon is then treated as a hadronic object with a structure function, which undergoes a collision with the beam proton. Similarly, single diffractive interactions in proton - proton collisions may be modeled by assuming that one of the beam protons emits a pomeron, again according to some flux formula, which subsequently undergoes an interaction with the other beam proton (see figure 1). HERWIG will automatically choose to radiate a photon from a beam lepton if a hard subprocess is selected which requires a hadronic structure for the beam lepton. Examples would be choosing HERWIG subprocess 1500 (QCD $2 \rightarrow 2$ scattering) in an electron - proton collision, or subprocess 9000 (deep inelastic scattering) in an e^+e^- collision.

All that is necessary therefore, to simulate a single diffractive interaction in a pp collision is to replace the photon flux with a suitable pomeron flux factor, and the

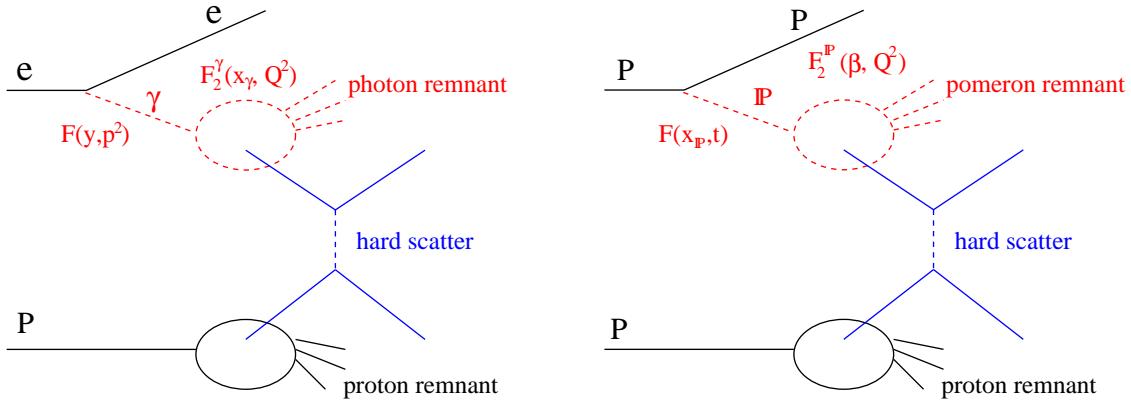


Figure 1: The POMWIG philosophy. Photoproduction in ep (or ee) collisions is replaced with pomeron or reggeon exchange in pp (or ep) collisions.

photon structure function with a pomeron structure function, and run HERWIG in ep mode rather than pp mode. The electron should then be identified with the proton which remains intact after the diffractive scattering. This process may be generalised to include sub-leading exchanges, and to perform double pomeron collisions and diffractive DIS as will be described below.

Our philosophy for POMWIG has been to make as few changes as possible to the HERWIG code. In particular, the HERWIG common blocks are left unchanged, and only two HERWIG subroutines have been modified. This approach has some disadvantages, in that we have left the event record unchanged. An intact proton will still appear as a lepton, therefore, and a pomeron will appear as a photon. We felt that such cosmetic inconveniences are outweighed by the overall simplicity and ease of installation and maintenance which are features of POMWIG .

2 Installing the Code

The code can be obtained on request from the authors, or from [2]. The routines supplied will function with all currently available versions of HERWIG from 5.9 onwards. There are two HERWIG routines which must be replaced: `HWSFUN` and `HWEGAM`. `HWSFUN` has been modified to call the H1 diffractive structure function routine `H1QCD` [3], or the user defined structure function routine `POMSTR` in the case of pomeron exchange, or to use a neutral pion structure function in the case of reggeon exchange. The pion structure is taken from the CERN `pdflib` package via a call from `HWSFUN`. The default reggeon structure is that of Owens [4], as used in the H1 diffractive DIS analysis [3]. `HWEGAM` substitutes the H1 pomeron or reggeon flux for the photon flux. The flux itself is calculated by the new routine `FLUX`.

If beam particle 1 is the electron (playing the role of the diffracted proton), then setting HERWIG parameter `MOPPDF(1) = -1` and `NSTRU = 6` will cause the H1 pomeron structure function to be used for beam particle 1. Similarly, setting `NSTRU = 7` will select reggeon exchange, and `NSTRU = 8` will select the user defined

pomeron structure from **POMSTR**. The parameters in the H1 pomeron structure function routine are set via an initialisation call to **H1QCD**.

To initialise the H1 pomeron structure function, the call should be made from the **HERWIG** routine **HWABEG** as follows;

```
INTEGER ifit
DOUBLE PRECISION XPQ(-6:6),X,Q2
Q2=75
ifit=5
X=0.1
call QCD_1994(X,Q2,XPQ,ifit)
```

Details of the parameters can be found in the **H1QCD** routine. The above parameters select the LO fit 2. For this initialisation call to **H1QCD**, the values of **Q2** and **X** are irrelevant.

The **HERWIG** parameters **Q2WWMN** and **Q2WWMX** set the minimum and maximum pomeron virtualities, t_{min} and t_{max} respectively. **YWWMIN** and **YWWMAX** set the minimum and maximum incoming proton energy fractions carried by the pomeron, x_{IP}^{min} and x_{IP}^{max} respectively.

The default parameters for the pomeron and reggeon fluxes are those found by the H1 Collaboration in [3], for the case in which no interference is assumed between the pomeron and reggeon contributions to $F_2^{D(3)}$, as shown in table 1¹. The fluxes are parameterised as

$$f_{IP/p}(x_{IP}) = N \int_{t_{max}}^{t_{min}} \frac{e^{\beta_{IP}(t)}}{x_{IP}^{2\alpha_{IP}(t)-1}} \quad (1)$$

$$f_{IR/p}(x_{IP}) = C_R \int_{t_{max}}^{t_{min}} \frac{e^{\beta_{IR}(t)}}{x_{IP}^{2\alpha_{IR}(t)-1}} \quad (2)$$

where $\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP}t$ and $\alpha_{IR}(t) = \alpha_{IR}(0) + \alpha'_{IR}t$. In the case of the user defined structure functions, $N = 1$ by default, and the normalisation may be included within **POMSTR** or **FLUX** at the users discretion. The normalisation of the flux is arbitrary in the case of the H1 pomeron structure function. The **H1QCD** routine is implemented such that the generated cross section will always match $F_2^{D(3)}$ as measured by H1 at $x_{IP} = 0.003$, irrespective of the parameters chosen for the flux.

¹Note that the reggeon parameters are not well constrained by current measurements. The defaults are those used to generate the curves in figure 2.

Quantity	Value
α_{IP}	1.20
α_{IR}	0.57
α'_{IP}	0.26
α'_{IR}	0.90
B_{IP}	4.6
B_{IR}	2.0
C_{IR}	48

Table 1: The default parameters in POMWIG

Process	BEAM1	BEAM2	MODPDF(1)	MODPDF(2)	NSTRU
$PP \rightarrow PX$	P	$E+$	pdf1lib	-1	6 (7, 8)
$PP \rightarrow PPX$	$E+$	$E+$	-1	-1	6 (7, 8)
$eP \rightarrow ePX$	$E+$	$E+$	N/A	-1	6 (7, 8)

Table 2: The diffractive processes available in POMWIG

3 Summary of available processes

The processes currently available in POMWIG are summarised in table 2. The particular hard subprocess required is set as usual via HERWIG parameter `iproc`. Note that at present for double pomeron exchange, it is only possible to simulate pomeron - pomeron or reggeon - reggeon collisions, and not pomeron - reggeon. In diffractive DIS (`iproc=19000`), the pomeron is always emitted from the second beam particle. Note also that process $eP \rightarrow ePX$ in table 2 refers only to diffractive DIS. POMWIG is unable at present to generate this process with a resolved photon component.

4 Example processes

In order to make the modifications clear, we shall consider the simulation of several example processes in both ep and pp collisions. First, we consider the diffractive structure function $F_2^{D(3)}$ as measured by the H1 Collaboration at HERA [3]. The complete list of modifications to the HERWIG main program in order to generate pomeron exchange events using the H1 pomeron structure are as follows :

```

PROGRAM HWIGPR
C---BEAM PARTICLES
PART1='E+' 
PART2='E-' ! diffracted proton
C---BEAM MOMENTA
PBEAM1=27.6
PBEAM2=820.
CALL HWIGIN
MODPDF(2)=-1
iproc=19000 ! DIS hard subprocess
NSTRU=6 ! selects H1 pomeron structure routine
Q2WMN=1.E-6 ! minimum t
Q2WMX=4. ! maximum t
YWWMIN=.00299 ! minimum  $x_{IP}$ 
YWWMAX=.00301 ! maximum  $x_{IP}$ 
Q2MIN=11.9 ! minimum  $Q^2$  of DIS photon
Q2MAX=12.1 ! maximum  $Q^2$  of DIS photon

```

The event record is shown in table 3. The diffracted proton is represented by entry 5, labelled **E-**. Entry 4, labelled **GAMMA** is the pomeron. The incoming positron, entry 6, scatters off a **UBAR** quark in the pomeron, entry 7. The complete $F_2^{D(3)}$ as generated by POMWIG with the default parameters is compared to the H1 measurement [3] in figure 2. POMWIG fails only in the highest β bins, that is at low diffractive masses, because the contribution from diffractively produced mesons is not included in HERWIG .

In PP collisions at the Tevatron, we consider two example processes, diffractive dijet production and Higgs production via pomeron-pomeron fusion. The single diffractive process $P\bar{P} \rightarrow PX$ is shown in table 4. For this process, HERWIG parameter **iproc** should be set to 11500. If diffractive W production were required, with the W decaying to electrons only, **iproc** would be set to 11451, and so on. The pomeron is represented in the event record by entry 4, labelled **GAMMA**. x_{IP} for this event is 0.0067. Entry 5 in the event record, labelled **E+**, is the scattered proton. In the hard subprocess, entry 6 is the parton from the pomeron, and entry 7 is the parton from the proton. β for this event is 0.22.

The double diffractive process $P\bar{P} \rightarrow P\bar{P}H$, for the Higgs decaying to $b\bar{b}$ is shown in table 5. **iproc=11605** selects Higgs production with the Higgs decaying only to $b\bar{b}$. In this case, the two pomerons are entries 4 and 6 in the event record, labelled **GAMMA**. Entries 5 and 7 are the intact scattered protons, and entries 8 and 9 are the partons from the pomerons which enter the Higgs production hard subprocess.

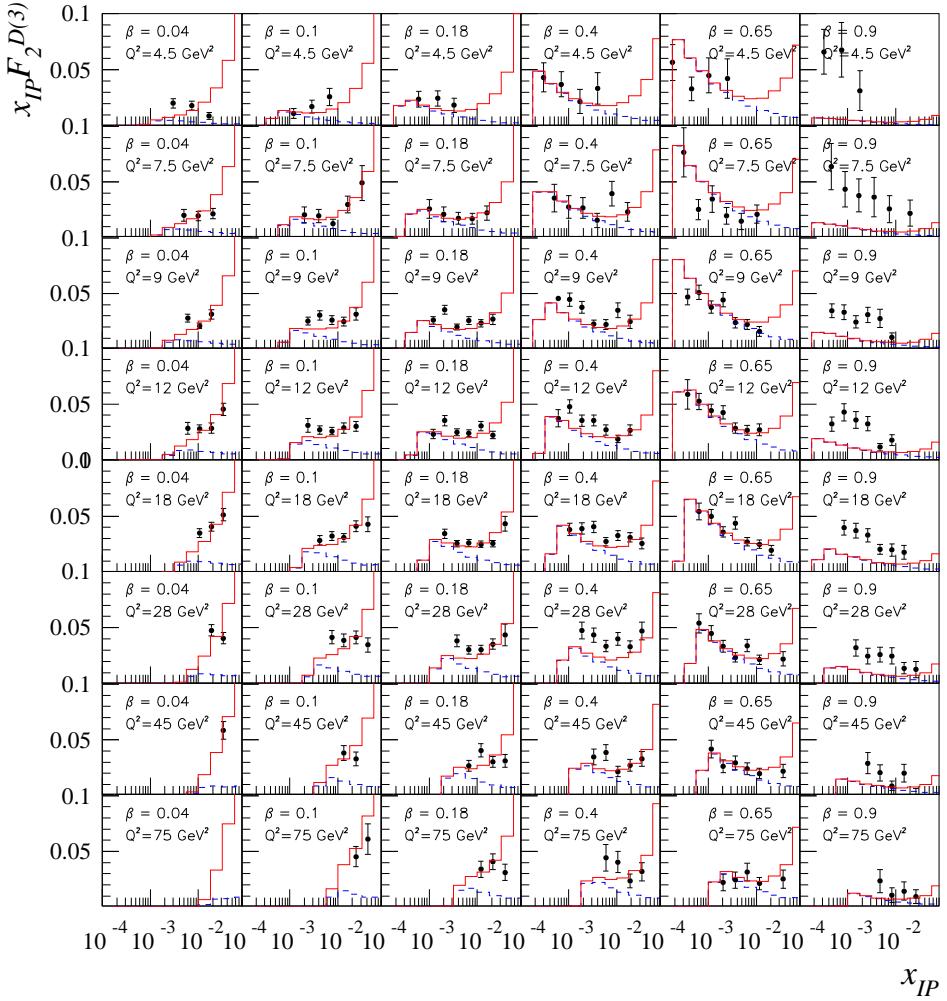


Figure 2: The diffractive structure function $F_2^{D(3)}$ as generated by POMWIG compared to the data of the H1 Collaboration [3]. The blue dashed line shows the pomeron contribution, and the red solid line shows the sum of the pomeron and reggeon contributions.

EVENT 1: 27.60 GEV/C E+ ON 820.00 GEV/C E- PROCESS: 19000
SEEDS: 313759 637835 STATUS: 100 ERROR: 0 WEIGHT: 1.4238E-04

—INITIAL STATE—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
1	E+	-11	101	0	0	0	0	0.00	0.00	27.6
2	E-	11	102	0	0	4	5	0.00	0.00	-820.0
3	CMF	0	103	1	4	0	0	0.20	0.41	25.1
4	GAMMA	22	3	2	0	0	0	0.20	0.41	-2.5
5	E-	11	1	2	0	0	0	-0.20	-0.41	-817.5

—HARD SUBPROCESS—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
6	E+	-11	121	8	6	11	6	0.00	0.00	27.6
7	UBAR	-2	122	8	10	12	10	0.05	0.10	-0.6
8	HARD	0	120	6	7	9	10	0.07	0.11	27.0
9	E+	-11	123	8	9	14	9	3.06	0.76	22.8
10	UBAR	-2	124	8	7	15	7	-3.01	-0.66	4.2
11	Z0/GAMA*	23	3	6	8	0	0	-3.06	-0.76	4.8

Table 3: Extract from a typical event record for diffractive DIS at HERA

EVENT 1: 900.00 GEV/C E+ ON 900.00 GEV/C P PROCESS: 11500
SEEDS: 313759 637835 STATUS: 100 ERROR: 0 WEIGHT: 0.1482E+07

—INITIAL STATE—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
1	E+	-11	101	0	0	4	5	0.00	0.00	900.00
2	P	2212	102	0	0	0	0	0.00	0.00	-900.00
3	CMF	0	103	4	2	0	0	-0.18	0.22	-893.98
4	GAMMA	22	3	1	0	0	0	-0.18	0.22	6.02
5	E+	-11	1	1	0	0	0	0.18	-0.22	893.98

—HARD SUBPROCESS—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
6	GLUON	21	121	8	7	11	9	-0.04	0.05	1.35
7	GLUON	21	122	8	10	15	6	0.00	0.00	-55.61
8	HARD	0	120	6	7	9	10	0.09	0.03	-54.25
9	GLUON	21	123	8	6	20	10	4.12	-0.99	-2.04
10	GLUON	21	124	8	9	26	7	-4.16	1.04	-52.22

Table 4: Extract from a typical event record for the single diffractive process at Tevatron Run I

EVENT 1: 1000.00 GEV/C E+ ON 1000.00 GEV/C E- PROCESS: 11605
SEEDS: 9876759 63576835 STATUS: 100 ERROR: 0 WEIGHT: 0.5181E-08

—INITIAL STATE—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
1	E+	-11	101	0	0	4	5	0.00	0.00	1000.00
2	E-	11	102	0	0	6	7	0.00	0.00	-1000.00
3	CMF	0	103	4	6	0	0	0.42	-0.24	56.61
4	GAMMA	22	3	1	0	0	0	0.04	0.17	98.46
5	E+	-11	1	1	0	0	0	-0.04	-0.17	901.54
6	GAMMA	22	3	2	0	0	0	0.38	-0.41	-41.85
7	E-	11	1	2	0	0	0	-0.38	0.41	-958.15

—HARD SUBPROCESS—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
8	UBAR	-2	121	10	9	11	9	0.03	0.15	82.80
9	UQRK	2	122	10	8	13	8	0.33	-0.36	-36.53
10	HIGGS	25	120	8	9	25	25	2.35	0.58	46.29

—STRONG HADRON DECAYS—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
25	HIGGS	25	195	10	25	31	32	2.35	0.58	46.29

—H/W/Z BOSON DECAYS—

IHEP	ID	IDPDG	IST	MO1	MO2	DA1	DA2	P-X	P-Y	P-Z
31	BQRK	5	123	25	32	33	32	-47.94	-1.24	48.97
32	BBAR	-5	124	25	31	35	31	50.29	1.82	-2.69

Table 5: Extract from a typical event record for Higgs production via pomeron-pomeron fusion at Tevatron Run II

References

- [1] G. Marchesini et al, Comp. Phys. Comm. **67** (1992) 465 ; G. Corcella et al, hep-ph/9912396
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- [3] H1 Collaboration: C.Adloff et al. Z.Phys. C74 (1997) 221.
- [4] J. F. Owens, Phys. Rev. D30 (1984) 943.